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OBSERVATIONS OF NON-SPHERICAL, GRAPHITE-EPOXY PROJECTILES IMPACTING A THERMALLY-INSULATED, DOUBLE-WALL SHIELD

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ABSTRACT

Introduction

The DebriSat hypervelocity impact experiment, performed at the Arnold Engineering Development Center, is intended to update the catastrophic break-up models for modern satellites. To this end, the DebrisSat was built with many modern materials including structural panels of carbon-fiber, reinforced polymer (CFRP). Subsequent to the experiment, fragments of the DebrisSat have been extracted from porous, catcher panels used to gather the debris from the impact event. Thus far, one of the key observations from the collected fragments is that CFRP represents a large fraction of the fragments and that these fragments tend to be thin, flake-like structures or long, needle-like structures; whereas, debris with nearly equal dimensions is less prevalent. As current ballistic limit models are all developed based upon spherical impacting particles, the experiment has pointed to a missing component in the current approach that must be considered. To begin to understand the implications of this observation, simulations like those shown in Fig. 1 have been performed using cylindrical structures at a representative orbital speed into an externally-insulated, double-wall shield that is representative of shielding of International Space Station visiting vehicles. These simulations have been performed for normal impacts to the surface with three different angles-of-attack (AOA) to capture the effect on the shield performance. This

paper documents the simulated shield and the models developed to study the effect of non-spherical fragments, as well as, derives the critical characteristics of CFRP impacting particles for the selected shield as shown in Fig. 2. To assist with the design of the updated debris models, this work summarizes the simulated results into a deployable form for evaluating the relative importance of fragment structures.

Figures

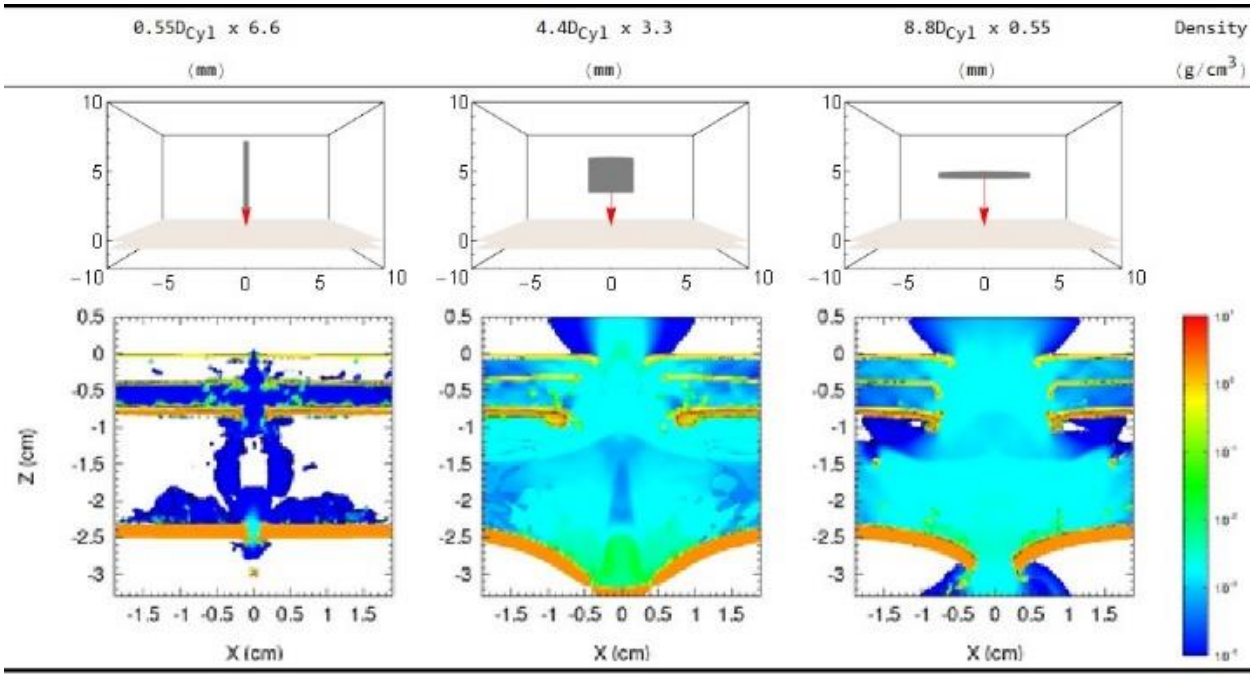

Fig. 1 Density contour plots of super-critical, normal-impact simulation of a right-circular cylinder with the central axis aligned with the velocity vector into the Soyuz Orbital Module double-wall shield. Cylinder diameters considered are 0.55mm, 4.4mm and 8.8mm. The density contour shown is after 30μs of impact evolution.

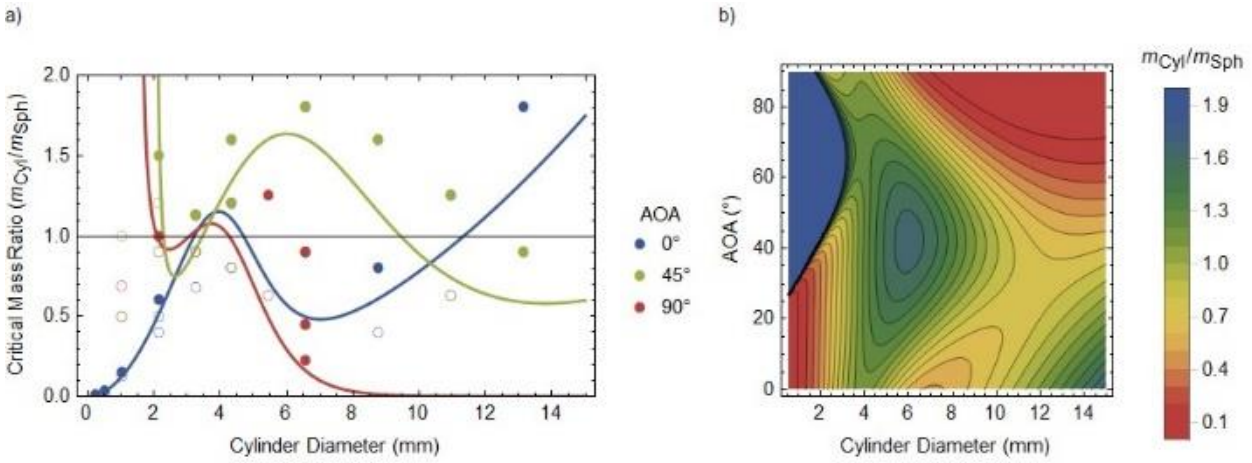

Fig. 2 Critical particle mass of a cylinder relative to a sphere a) for AOA of 0°, 45° and 90° as a function of cylinder diameter (perforated as solid and intact as open with the empirical model as lines) and b) a contour plot from the interpolation of the empirical model over cylinder diameters and AOA.

Acknowledgements

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